Canadian Railway Club

Discussion on

"THE USE OF PULVERIZED COAL FOR GENERATING STEAM"

Paper read by

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Use of Pulverized Coal
for
Generating Steam

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Coal in pulverized form has been used for the generation of steam for about the last 30 years more or less successfully. However, it is only in the last 8 or 10 years that one can say it has come into its own, and at the present time it is being used extensively for the efficient generation of steam in both small manufacturing plants having boilers from 70 H.P. up and large plants having boilers up to 2,000 H.P.

The first pulverizer patent was taken out in 1807, and from that time on apparently no effort was made to use coal in powdered form until the year 1870. A description of this system is in the "Proceedings of the Institute of Civil Engineers" Vol. 44, page 289, and also in the "Journal of the Iron and Steel Institute" of 1873, page 91.

Since 1870 the effort to use this form of fuel was renewed from time to time in revolving furnaces, heating and puddling furnaces, but very little effort was exerted to use it under boilers until after 1900, and it is doubtful whether there was a boiler in commercial operation using pulverized fuel at that time in the United States.

In 1905, Mr. Frederick Seymour and Mr. Claude E. Bettington approached the New York Edison Company, 55 Duane St., New York City, concerning the installation of a powdered coal unit on one of their boilers, and it was decided to instal an Aero pulverizer and a specially designed furnace in front of a 638 H.P. Aultman and Taylor boiler. This furnace embodied the results of extensive experiments conducted by Mr. Bettington in Johannesburg, South Africa, previous to this time.

Boiler known as No. 22 was set aside for the experiment and the furnace installed in the front of the boiler was brick lined and had inside dimensions of 5′ 8″ diameter and 15′ 0″ high. A 14″ diameter straight shot burner was installed in a vertical upward position through the bottom of the furnace, and the products of combustion were taken from the side of this furnace near the bottom, approximately in line with the burner mouth, and then permitted to travel over the heating surface of the A. & T. boiler.

Two 3000 pound Aero units were used on this job and the furnace above described was able to take care of all the coal that could be supplied, but such high temperatures were obtained that the furnace brickwork and burner end burned away in a very short time, and as to be expected the lower part of the furnace was the most damaged, the upper part showing no signs of deterioration.

Following these experiments a boiler known as the Bettington boiler was designed for the use of pulvedized coal having its vertical circular furnace arranged in the centre of the boiler's vertical water tubes, the tubes next to the furnace space being covered with special brick, forming a brick lined furnace enclosure. The burner was installeed in a similar position as at Duane St., namely, at the bottom of furnace and fired vertically upwards, the products of combustion passed into the boiler tubes through an annular opening near the bottom of the furnace.

A boiler of this design was built and installed about 1914 for the Canadian Railways plant at Moncton, N. B., for supplying steam to their workshops, and from reports is still in operation.

In 1913 more experiments were made on a 300 H.P. Franklin boiler, using pulverized coal for fuel. This boiler had a long low furnace, when first installed, and after experimenting with this type of furnace for some time, it was found unsatisfactory, and it was decided to alter it in such a manner as to obtain a high furnace of large volume in the form of an inverted cone with the burner firing at about 45° to the horizontal. When this new furnace was first fired up it was immediately observed that a vast improvement had been made and the boiler was operated almost continuously for about 2 years with boiler maintenance costing practically nothing. We are not able to determine at what rating this boiler was

run, but in all probability it was not operated very much above rating. Mr. W. G. Freer, who at that time had charge of the boiler stated that the success of this installation was due not only to the design of furnace, baffle walls and burner, but to the proper control of the flame, that is to say, it is essential to have neither too hot a flame due to lace of air, nor too cool a flame with excess air, and today it is very desirable that the engineer keep these points in view.

At the present time it has been thoroughly demonstrated that the use of coal in powdered form is a most desirable way to produce heat for the generation of steam. Some of the many advantages to be obtained by this method are:

1. A heavy boiler load can be quickly picked up or dropped as the case may be by simple adjustments of the coal and air feeds without undue waste of fuel.

2. No losses occur due to clinkering or cleaning of fires.

3. Changes in the quality of the coal cause little loss in boiler capacity or efficiency due to the ease of increasing or decreasing the amount fired, and adjusting the requisite amount of air.

4. The feeding mechanism of a pulverizer can be adjusted quickly so that size of coal does not affect the boiler capacity or efficiency.

5. Furnace conditions can be maintained easily for the most economical combustion at whatever boiler rating is desired and almost instantaneous changes in boiler rating may be made and still maintain the most economical combustion in the furnace. Hence, an even combined efficiency curve may be maintained at all times.

6. The loss of combustible in the ash from a properly designed coal burner and furnace is reduced to a minimum no matter what variation is made in the boiler rating within the designed limits.

Pulverized or powdered coal as used today is coal that has been reduced to a fine powder by mechanical means so that it can be conveyed to the furnace easily by means of a screw conveyor by compressed air or it can be conveyed direct from the pulverizer by means of low pressure primary

or carrier air to the inside of the furnace in which it may be burned in suspension when mixed with the necessary amount of secondary air to support combustion.

There are two systems in general use for preparing pulverized coal, namely, the central system and the unit system.

Central System

The Central System was designed originally so that the crushing, drying, pulverizing and storing was done in a building separated from the boiler room. From this building the prepared pulverized coal is conveyed, either by screw conveyors, compressed air, pumps or low pressure air, to small coal hoppers in front of boilers ready for distribution in the furnace through pipes, or is conveyed directly into the furnace without the use of the boiler room hoppers. The pulverizing unit of this system will produce from 6000 pounds to 40,000 pounds of prepared coal per hour.

Unit System

The Unit System derives its name from the combination of pulverizer, feeder, dryer and fan in one integral unit, hence—Unit System. Modifications of this arrangement, of course, are available to reduce boiler shut downs due to the occasional pulverizer repair, such as having two pulverizer units per boiler, each pulverizer supplying one, two or three burners depending on how many burners are installed in the boiler. These units are compact and built in sizes ranging from 200 pounds to 15,000 pounds of pulverized coal per hour delivered at the burners and cover a floor area ranging from 7.5 square feet to 39 square feet, and are usually placed immediately in front of or alongside of the boiler to be fired. The powdered coal is fired directly as pulverized, no intermediate storage being necessary. Fluctuations of boiler load being taken care of by increasing or decreasing the amount of coal being fed to the pulverizer.

Coal Drying

In the Central System above referred to it is usual to dry the coal after having crushed it to about ¾″ size to a moisture content of not more than about 2%. The principal reason for drying the coal in this system being:—

1st—Wet pulverized coal packs and bridges in storage bins;

2nd—Wet pulverized coal tends to clog the screw conveyors;

3rd—Wet pulverized coal requires considerably more power for grinding;

4th—Wet pulverized coal presents difficulties in separation of particles at the burner.

Originally drying was accomplished by the burning of coal in a furnace which was part of the dryer and passing the products of combustion over and through the coal, the hotter gases passing around the outside of a rotating shell through which the coal to be dried is passed. The gases having cooled down are now passed through the interior of the rotating shell coming directly in contact with the coal, direction of flow being opposite to the coal flow.

Dryers of this design should be chosen too large rather than too small, so as not to use too high a drying temperature that is liable to drive off volatile from the coal which will be lost in the escaping flue gases.

The approximate power required to rotate the shell of a dryer of this design is:

25 ton per hour dryer requires 10 H.P.

2 ton per hour dryer requires 2 H.P.

The method of drying described above is now almost entirely obsolete in the Central System of coal pulverization. Waste heat coal dryers utilizing diluted flue gases as a drying medium are being used, and also coal is now being dried directly in the pulverizers themselves in a manner which will be described later for the Unit System.

In the Unit System it is not so important to dry the coal before puverizing as there are no screw conveyors or storage bins for the finished product, and also during the process of pulverizing the coal is partially dried with warm air in constant circulation which continually keeps the particles separated until finally discharged into the furnace.

However, the same is true of this system as of the Central System concerning the power required to pulverize coal when

wet; both systems consuming more power proportionately as the moisture content in coal goes up. However, this condition is helped considerably by the introduction of hot air at the feed end of the machine, so that this hot air passes through the coal during the process of pulverizing. The powdered coal and steam thus formed are carried in suspension with the low pressure carrier air to the burner and so on into the furnace.

Fineness

This is a very much discussed subject among engineers and opinions differ from all through a 200 mesh screen to as low as 40% through a 100 mesh screen. It can readily be seen that in any system of pulverizing as the fineness is increased so does the power to pulverize increase per ton delivered, and again, as the moisture in the coal increases so does the power to pulverize it to a given fineness increase per ton of coal delivered, so that to bring the power required to pulverize a ton of coal within reason, provided the moisture content is constant, a certain fineness can be produced that is entirely satisfactory for burning purposes.

It is more logical to measure fineness of pulverization by the percentage remaining on the coarser mesh screens than by what will pass through a 200 mesh screen, as what remains on the coarser mesh screen bears more important relation to good combustion than the finer coal. Two different coals may show a great similarity in the percentage through a 200 mesh, yet that remaining on the coarser screen may vary 100% or more, so that if a definite limit was set on the percentage of coarse fuel, better combustion would result.

There seems to be no doubt that due to the increased surface exposed, the finer the pulverized product the easier it will burn, or putting it in another way, the quicker it will burn, provided the particles are kept separated and supplied with oxygen until complete combustion of the particle has been effected. However, due to the extra power required above normal to produce this extra fine coal, which at once increases the cost per ton of coal delivered, this extra fineness above normal is not necessary for the overall efficiency aimed for, provided a burner be so designed as to give mixture of such a nature as to continually remove the carbon dioxide gas envelope from the particle of coal and supply this particle with fresh oxygen, the whole problem seems to resolve itself into time, distance and speed.

Distance in the form of length of travel which is closely related to time can be obtained in conjunction with speed by a zigzag path and not in a straight line, change of direction of the particle tends to dislodge the CO_2 envelope so that the particle of coal may come in contact with the necessary oxygen for continuous combustion.

Burners

There are a great number of pulverized coal burner designs being offered the purchaser today, all of which possibly may be divided into two classes, namely:

1st—Straight shot burner.

2nd—Turbulent burner.

Both of these classes of burners are designed to supply the furnace chamber with a quantity of separated pulverized coal particles intermingled with its carrier air. Some perform this all important feature of discharging an even mixture of coal and air of the proper density throughout the entire area of the burner mouth and some do not.

In a straight line burner where length of travel is in a comparatively straight line the particle of coal is either forced or falls into the furnace chamber at a given speed, the solid particle of coal due to its solid nature tends to fall, whilst the rush of air through lower openings in the furnace tends to pull it upward and according to the depth of furnace the size of particle, and the position fo the secondary air supply inlet to furnace, so will be the carbon content in the ash. In a burner of this description the furnace draft and gravitation appear to be the agents used for the disengaging of the CO_2 envelope from the coal particle and there are a vast number of such burners in successful operation today.

The straight shot burner apparently was the first to be designed and is still used in about 65% of the installations being made today, its simplicity of construction and possible variation in the shape of the burner mouth lends itself for use in almost any style of furnace of the proper volume, also it may be installed in the furnace at any angle from the horizontal to the vertical.

This type of burned gives a U shaped flame and requires a longer travel than the turbulent type and as there are a number of boiler designs that have a comparatively short but

high and wide furnace, burner of the straight shot type may be installed in it to fire almost vertically down through the roof of the furnace extension as shown in Figure 1.

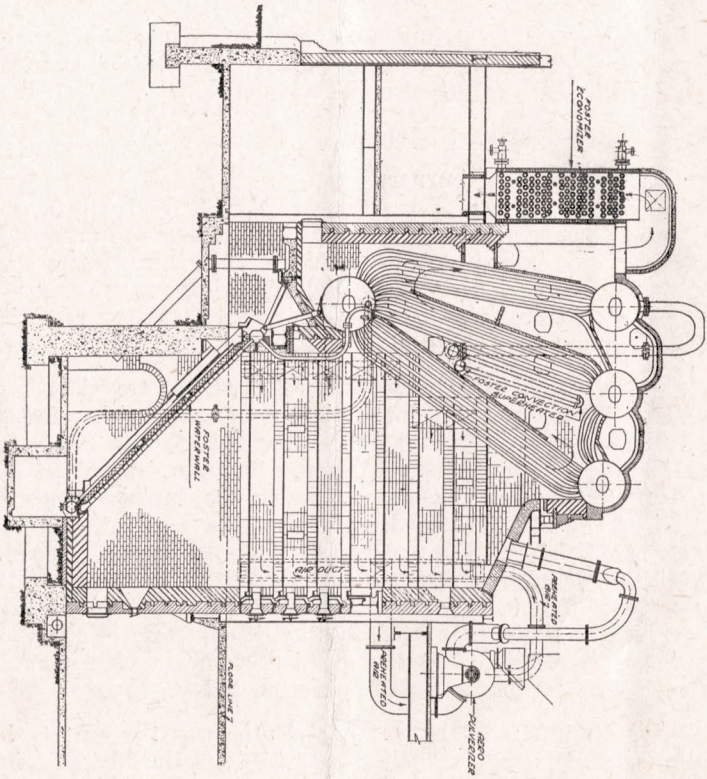


Fig. 1. View showing straight shot burner firing down through roof.

or it may be installed at a very steep angle near the top of the furnace front wall at a steep angle as shown in Figure 2.

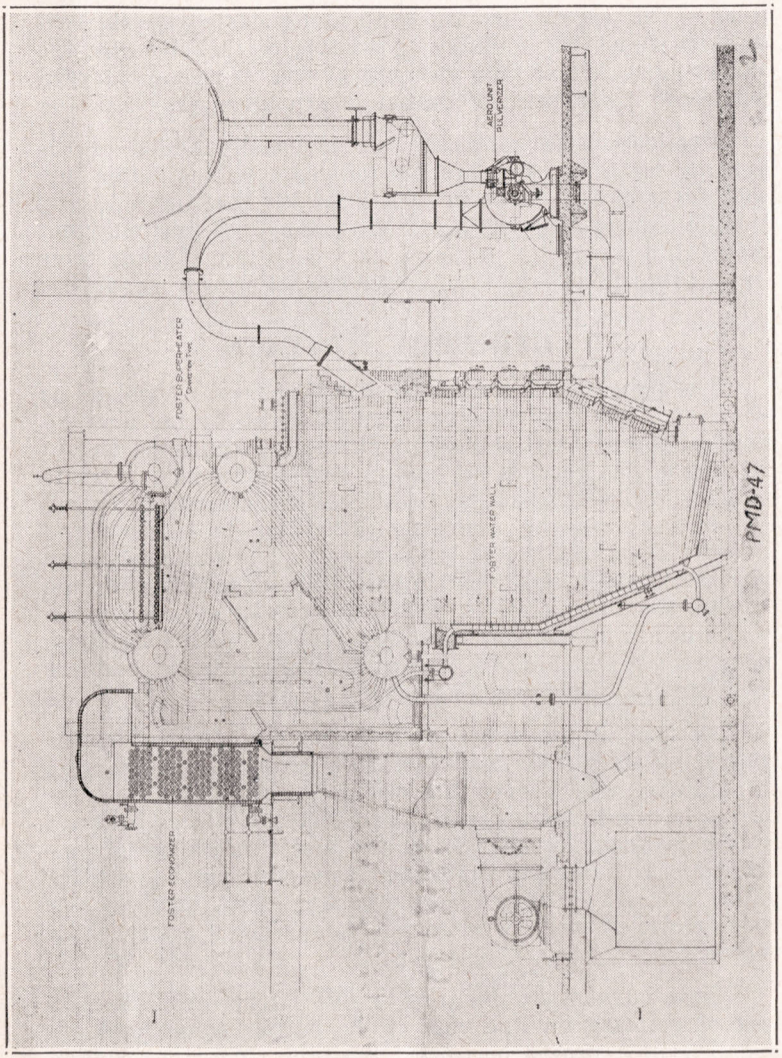


Fig. 2. View showing straight shot burner installed in front wall of furnace at a steep angle.

all with the purpose in view, depending upon the type of furnace wall construction, of giving the coal travel length

enough to complete combustion before it enters the boiler tubes. This type of burner is not designed to give the coal and carrier air any mechanical twisting or turbulance at the burner mouth, other than insuring an even density discharged from each square inch of burner mouth area.

Combustion or secondary air is usually added to the burning coal steam through controllable openings in the furnace front or side walls in such positions that the incoming air due either to the stack pull or forced draft fans may mix thoroughly with the products of combustion during their travel toward but before they reach the boiler heating surface.

Turbulent Burners

The principle of turbulence has long been recognized as essential in the combustion of fuel as shown by the development of forced draft stokers, mechanical oil burners, and in the case of gas burners, all tending toward the more intimate mixture of the fuel and air as they enter the furnace. Turbulent burning may be accurately defined as an intimate and almost violent mixture of the fuel and all of the combustion air immediately before or immediately upon entering the furnace chamber in such a manner that complete combustion is obtained in the shortest space and time, and with a minimum of excess air, which means that each atom of carbon combines with two atoms of oxygen as quickly as possible.

As soon as pulverized coal was used under boilers for generating steam, the manufacturers turned their attention to the design of a burner that would produce a shorter flame having in mind that initial cost and upkeep of large furnaces in new pulverized coal installations, and also the use of pulverized coal on existing furnaces, and the possible use of pulverized coal on Scotch marine boilers, which have entirely water-cooled furnaces and are of comparatively very small volume.

These burners are designed to give a very turbulent mixture of primary air and coal at the burner mouth and are installed in a nearly horizontal position. The construction is such as to obtain a rapid relative velocity of primary air and coal to whirl either on its way to the burner outlet or immediately at the exit of the burner outlet, thus compelling the coal to take a tangential path on leaving the burner mouth causing the coal to move faster than the air. This design of

burner has no doubt shortened the flame and for horizontally fired boilers it has reduced the flame impingement of the rear wall and tends to fill the furnace full of flame. With this type of burner the secondary or combustion air is usually taken in around or through the burner. See figure 3 showing turbulent burner installation.

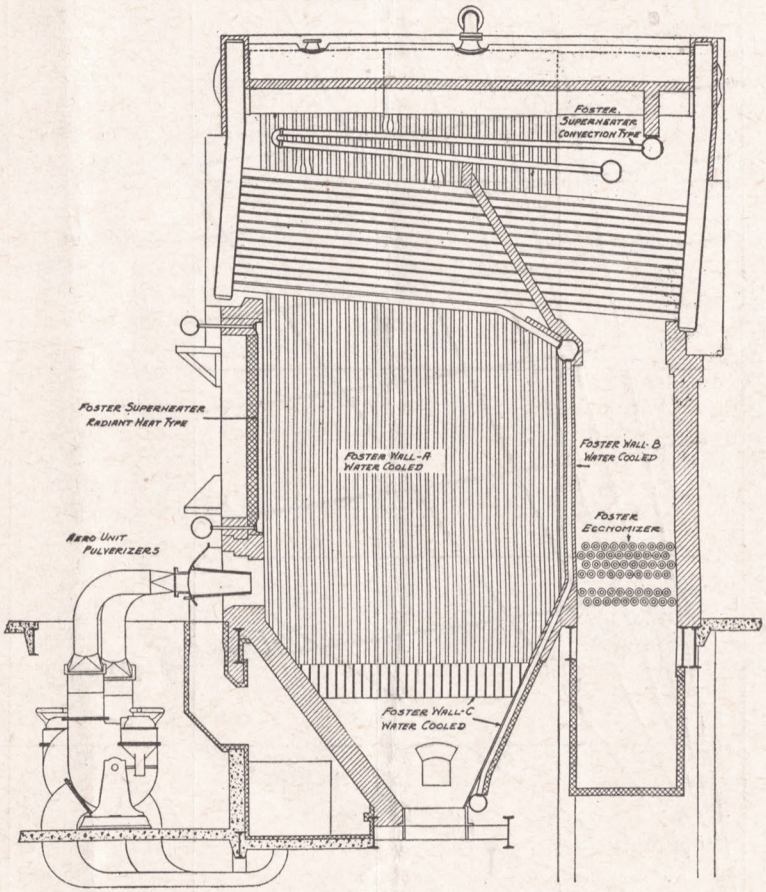


Fig. 3_2 View showing turbulent burner installed in a horizontal position in front wall.

The primary air and coal velocity leaving the burner mouth should not be less than 30 ft. per second, and it has

been demonstrated that velocities very much higher have been used with great success.

The pounds of primary or carrier air per pound of coal varies according to the rating, being lower at the high rating and higher at the low ratings, ranging from about 2 to 10 pounds of air per pound of coal.

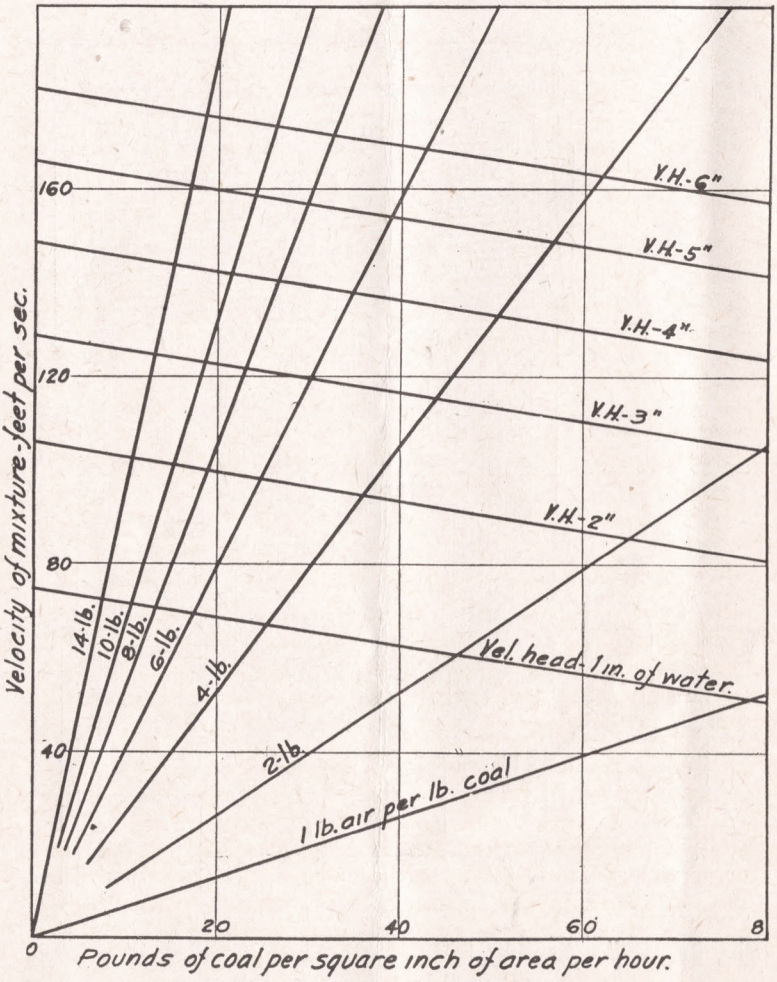


Fig. 4 Showing relation between coal velocity of mixture and velocity head for mixtures of coal and air at 200 deg. Fahr.

Furnaces

In furnaces designed to be put under Steam Generating units, size or volume is of paramount importance for the best combustion of the fuel, and for general purposes the following B.T.U. liberation may be considered as safe:

With coal having 2400°F ash fusion point, about 16,000 B.t.u. liberation per cubic foot volume for a solid brick lined furnace.

With coal having 2400°F. ash fusion point up to 19,000 B.t.u. liberation per cubic foot volume of furnace for air cooled walls.

With coal haxing 2400°F. ash fusion point, up to 19,000 B.t.u. liberation per cubic foot volume of furnace for water cooled walls.

This gives a general idea of the furnace volume required but does not give us the shape of furnace, which is dependent on the kind of burner used However, as the furnace is designed first, then the best type of burner for that particular furnace design is chosen, and, as naturally the initial expense is considered, floor space, furnace height and width, etc., are cut down to a minimum, whilst the maximum boiler rating is desired.

The continual progressively high demands of the purchasers are what makes it necessary for the manufacturers to experiment and develop apparatus that will meet these high demands and it may be said that the manufacturers are supplying these high demands very satisfactorily as demonstrated by the great increase of sales in the pulverized coal equipment.

In designing furnaces for the combustion of pulverized coal, thought must be given to the shape, so that the entering pulverized coal may be raised to a temperature at which it will burn immediately on entering the furnace. This particular temperature is dependent on the chemical and physical properties of the coal, and is lower, as the volatile content goes up, and the ash and moisture content goes down and as the fineness of pulverization increases. This temperature of ignition will be reached more quickly by the exposure of a large surface area of the incoming pulverized coal to the radiation of the furnace walls and flame.

As determined by Clement and Scholl of the Bureau of Mines the ignition temperature of average bituminous pulverized coal is about 1450°F. Once ignited the coal is burned rapidly and with a fair degree of completeness in almost any furnace, but for modern power plants the design of furnace must be such that the loss from coal leaving the furnace is negligible.

Temperatures maintained in pulverized coal furnaces depend largely on the fusibility of the ash content of the coal, the material of which the furnace is constructed and the method used for ash removal.

While it is conceded that the slower the mixture of coal and air is admitted to the furnace the less distance it will travel to receive the same amount of radiation, or in other words, it permits the heating of the mixture to the desired ignition temperature to be done in a shorter distance, but if it is travelling too slowly it will not permit the distribution of the flame throughout the mass, actually stopping flame propagation, due to the fact that there is not enough velocity to the coal particle to be able to detach itself from its surrounding carbon dioxide envelope so that further combustion of the particle may be continued by its receiving fresh oxygen from the surrounding air. Turbulence is the result of relative velocity of air and coal, change of direction or retardation of the coal particle has the property of increasing the spread of flame through the mixture. In fact the eddies set up by a turbulence of the entering mixture and the surrounding atmosphere in the furnace has an enormous effect in hastening flame propagation, and the final combustion of the particle of coal, and it is quite conceivable that by the continual fast disengaging of the CO_2 envelope around the coal particle, this particle of coal could be stationary in the furnace and be consumed in the fraction of a second if supplied with the necessary oxygen to continue its combustion.

In designing a furnace to insure the almost complete combustion of the fuel, it is necessary also to design it so that the cost of maintenance will be low and that the ash may be removed without difficulty.

To reduce the wall maintenance, water-cooled walls are frequently used. These water walls being a series of tubes shaped to conform to the inside of the furnace and connected up to the circulation of the boiler. A furnace may be com-

pletely water-cooled in this manner or only water-cooled in part as the case may be. Where water-cooling of furnace is considered too costly and not warranted, the brick walls are air-cooled, and the air thus heated is drawn or forced into the pulverizing unit to aid in the drying of the coal and also used as an aid to combustion by either forcing or drawing it into the furnace as secondary combustion air.

Where refractories are used for the lining of furnace, troubles from slag forming on the walls will occur if great care is not exercised to insure the flame not impingeing on the walls. This trouble is further lessened by the use of a greater supply of excess air, thereby reducing the percentage of CO_2 and temperature in the furnace.

Smoke

With the use of powdered coal in a properly designed furnace, smoke at the stack is of rare occurrence, but it can be caused by:

1st—Improper adjustment of the air supply;

2nd—Flames turning up and passing through the boiler tubes before complete combustion;

3rd—Too high a rate of combustion for the furnace volume.

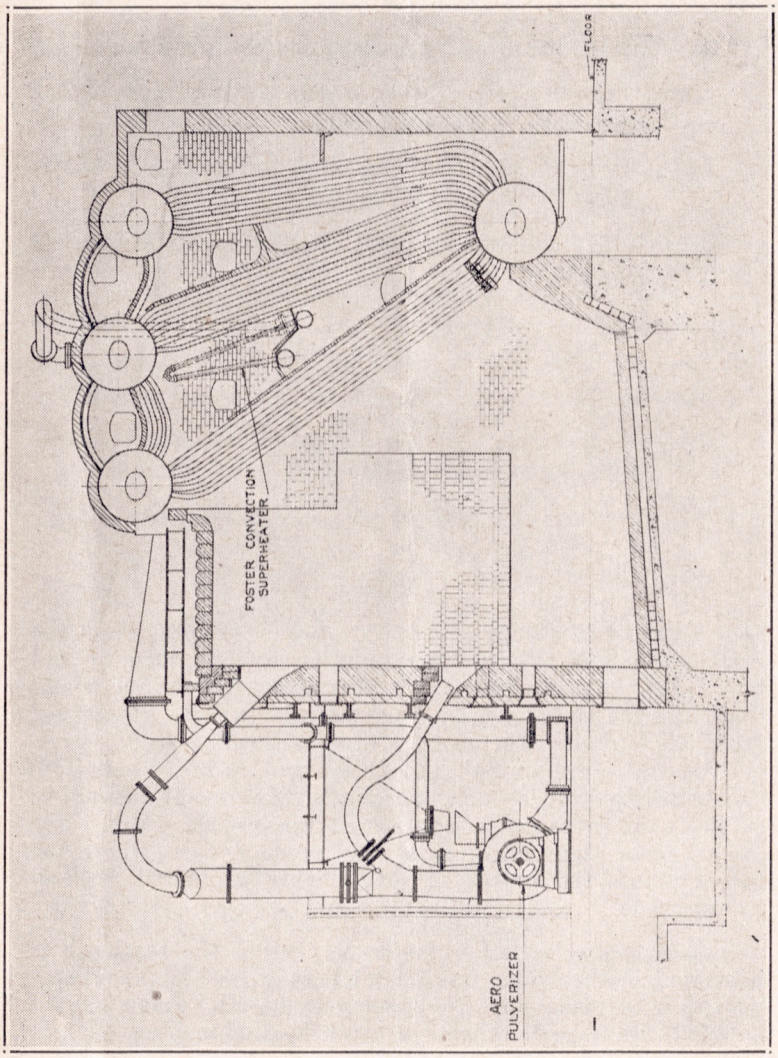
As an unlimited number of pulverized coal burners may be installed in the furnace of our modern boiler, it is important that each burner be supplied with an equal amount of coal, so that the amount of secondary air being admitted to the furnace may be used up, and if the boiler steaming rate must be increaseed or decreased, it is important that the operator change his air valve to correspond with the coal load and keep all the flames from the several burners about the same length.

Flames may turn up into the tubes before descending low enough into the furnace and cause smoke. This condition is probably caused by the burner primary air and coal velocity being too low, this condition causing the incoming coal to be turned up into the tubes of the boiler by the air rising in the furnace before complete combustion is effected, the remedy for this naturally is to either increase the burner velocity or decrease the stack draft or both.

If the flame strikes the tubes because the rate of combustion is too high, adjusting the drafts and air supply will do no good, usually it can only be prevented by reducing the capacity of the burners. From the above it can be seen that a furnace must be designed to accommodate the maximum rating of boiler anticipated.

High boiler ratings of 350 to 400 percent are being obtained without difficulty and good efficiencies at this rating are a prevailing occurrence.

When large units are installed with all the accessories such as air preheater, superheaters, economizer, water walls, etc., an efficiency of 87 to 88% can be obtained at moderate ratings. It is often necessary to operate boilers at full load during 5 or 6 days a week and on Saturday and Sunday only a small heating load is required. These conditions have been met very satisfactorily by the installation of an auxiliary coal conduit is connected to a small burner installed in the coal conduit is connected to a small burner installed in the front of boiler and can be used for low load conditions as shown in Figure 5.


FLOOR
FOSTER CONVECTION
SUPER-HEATER
AERO
PULVERIZER

Water Walls

Advantages to be gained by the use of watere wall construction for furnaces are as follows:

1st—Higher rates of heat liberation are possible;

2nd—Operation with lower excess air and the higher temperatures are permissible;

3rd—Minimum of air leakage and infiltration into furnace;

4th—Wider selection of coals of varying ash content is possible;

5th—Greater steaming capacity of the boiler unit is obtained due to heat absorbed in the water walls.

6th—Wall erosion or clinker formation is prevented;

7th—Greater furnace heat liberation capacity permits reducing furnace volume;

8th—Furnace and wall maintenance is reduced.

Ash

There is no excuse for black smoke emerging from the stack of a properly designed powdered coal furnace and burner, but as part of the ash is drawn through the boiler and flues into the stack, a light gray material will be discharged from the top with the products of combustion. At the present time there are a number of fly ash and coal dust collectors on the market which claim to separate and deposit 80 to 85% of the total entrained ash before it reaches the stack. The use of these dust collectors is only recommended where the larger plants are located in very thickly populated residential districts.

It is probable that some 15 percent of the total ash is deposited in the boiler passes and it is advisable that ample provision be made for soot blowing and dust pockets should be made and used, otherwise good heat absorbing surface will be cut off from the hot gas flow, the ash to be blown from these pockets is very light and easily taken care of provided periodic blowing is resorted to.

With the use of low fusion ash coals, there are occasions when the lower rows of boiler tubes will slag over when the heat release per cubic foot of combustion volume is high, especially when a refractory is used in the furnace, this is due to the fly ash being in a molten state at the time it strikes the tubes, gradually collecting until the entire opening between the tubes is bridged over or nearly so, apparently the best remedy for this is to use enough water wall surface in the furnace to insure the solidifying of this molten slag in suspension before reaching the tubes by heat transfer into the cooler water wall surface, then these solid slag particles will, if fine enough, pass up between the tubes or if heavy enough will fall to the bottom of furnace where it can be removed. Where this trouble is acute, a wider than usual gas passage is allowed for through the first one or two rows of tubes.

Ash removal from the bottom of the furnace is easily accomplished when it is kept in a floculent state, and not slagged.

Slagging

The slagging of the ash is caused by

1st—Using a low ash fusion coal;

2nd—Flame being too long;

3rd—By liberating too high a B.t.u. per cubic ft. volume of furnace.

From the above it is well to determine previous to the installation of a boiler unit.

1st—Maximum B.t.u. liberation per cubic foot volume of furnace;

2nd—The average Volatile in coal to be used;

3rd—The ash fusion point of the coal.

Because once the boiler and furnace is designed and built it is most expensive to change. With no two coals just alike it is always better to be on the safe side in regard to furnace design.

Owing to the fact that with the use of pulverized coal the excess air requirements are lowered 15 to 20%, the re-

sultant carbon dioxide content in the flue gases is increased and with properly water cooled furnaces CO_2 readings of 15 to 16 percent are obtained over varying load conditions, with brick lined furnaces it is not advisable to carry such high readings as the temperature obtained under these conditions will injure the brick work to such an extent as to cause expensive repairs necessary.

Marine Boilers

Great strides are now being made in the use of pulverized coal for marine purposes, and is being fired in Scotch boiler furnaces of small diameter successfully. These furnaces are entirely water cooled and as high as 58,000 B.t.u. release per cubic foot of combustion space is obtained, by combustion space in this case the combustion chamber at the rear of the furnace proper is added to the volume of the furnace chamber. With ash fusion temperature at 2350°F. no slagging of the ash occurs in the furnace, due to the close proximity of the water cooled furnace to the flame very high heat absorption occurs, thereby keeping the actual flame temperature down below temperature where ash will slag.

The S.S. "Mercer" of the U. S. Shipping Board having now been in more or less successful operation using pulverized coal for about a year, and at the present time pulverized coal installations are being made on a number of sea going tugs and cargo vessels.

In 1925 Mr. I. E. Muhlfeld, Consulting Engineer for the Kansas City Southern Railway Co., installed an Aero Unit pulverizer on one of the Mallet type Locomotives which hauls about 100 freight cars over a mountainous division about 200 miles long.

The combustion chamber of this particular engine is 12 to 14 ft. long, 9 feet wide and about 6 ft. high. A special tender was built to accommodate the pulverizer which is driven by a steam turbine, the tender was water jacketed in the usual way for the water supply, and the coal supply of about 16 tons is carried on the roof allowing a hollow space in the centre of the tender for the lengthwise installation of the pulverizer, the side outlet discharge from this unit being carried forward toward the rear end of the locomotive and connected to the burner installed in the furnace by means of a flexible connection.

The operation of the pulverizer feed and air inlets is effected by means of levers placed on the fireman's platform making it simple and quick for the picking up and dropping of the load as occasion demands.

The coal being used is known as Kansas Pittsburgh Slack, having about 8000 B.t.u. and 25% ash content.

This locomotive has been in operation ever since, and is making a considerable saving in labor and cost of fuel over the old method of firing by oil.

It is interesting to note that during the shop tests of the pulverizer used on this job, it was requested that the tests be made with the Unit inclined ¼" to the foot to determine the effect on the roller bearings, and during the last 2½ years no trouble has been experienced on the pulverizer due to climbing steep grades, sudden starts and stops other than the regular wear and tear due to pulverization. There seems to be no doubt as to the satisfactory performance of this locomotive because great interest is now being shown in the contemplated installation of similar units in several other locomotives in the near future.

In regard to small boiler installations, it is interesting to note that a small turbulent burner and Unit pulverizer has been supplied the Department of Mines, Ottawa, Canada, to be used on a small B. & W. boiler of approximately 70 H.P., with the intention of running experimental boiler tests using the various kinds of coal found in Canada.

From a survey of boiler installations it is interesting to note that at the present time about 850,000 rated boiler horsepower is being fired by pulverizeed coal, of which 400,000 is using the Unit System and 450,000 is using the Central System.

Since 1925 to date 165,000 rated horsepower has been or is now being installed using the Central System of Pulverization, whilst during this same period 310,000 rated horsepower has been or is now being installed using the Unit System of Pulverization, a gain of 145,000 rated horsepower for the Unit System over the Central System during the last two and one-half years.